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EFFECT OF SMOKELESS COMBUSTORS ON
PARTICULATES FROM J52 AND TF30
ENGINES

James E. Horling

Naval Air Propulsion Test Center
Trenton, New Jersey

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<p>Particulate samples using a modified LA Sampling Train were obtained from five J52-P-8B, three J52-P-6B and one each of J52-P-408, TF30-P-6C and TF30-P-408 gas turbine engines. The samples obtained were divided into solid particulates, solvent soluble material and water soluble material. Results indicate that smokeless combustors in the J52 engine reduce particulates by 20 percent. Results of TF30 tests are inconclusive because of limited sampling. The impact of smokeless combustor on stationary source regulations was also assessed.</p>		
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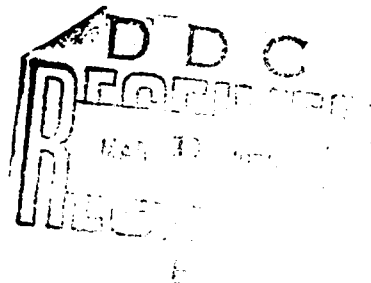
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INTRODUCTION.

1. Naval Air Rework Facilities (NARF's) have been cited by local air pollution authorities for exceeding regulations concerning exhaust stack smoke opacity from jet engine test cells. The smoke opacity problem has been remedied with the introduction of smokeless combustors in some models of J52 and TF30 gas turbine engines and by the use of the fuel additive ferrocene for other non-smokeless engines. As stated in reference a the smokeless combustors cause a reduction in the Ringelmann number of the test cell exhaust smoke to a value below one, which is the maximum limit for smoke opacity set by most local pollution control authorities. However, another test cell emission problem that needs to be considered, is particulate loading. There are local limits placed on particulate loading, but to date they have been generally unenforceable due to the lack of available unsophisticated particulate sampling equipment. This does not preclude the enforcement of these limits at some future date, however, when the state-of-the-art has advanced to allow uncomplicated and unambiguous particulate sampling. With this eventuality in mind, a particulate measurement program was conducted at NARF Alameda in accordance with reference b on TF30 and J52 turbine engines with and without smokeless combustors. The intent of this program was to evaluate the benefits of smokeless combustors in gas turbine engines in reducing particulate emissions from test cells. This study was authorized by the Ground Support Equipment Department (GSED) of the Naval Air Engineering Center (NAEC) through Project Order Number P.O. 4-8012 dated 5 October 1973.

2. The program was conducted in two parts in order to conform with the availability of the required engines at NARF Alameda. The tests took place during 24 April to 8 May and 16 June to 28 June 1974. A total of five J52-P-8B's, three J52-P-6B's, and one each J52-P-408, TF30-P-408 and TF30-P-6C were tested. The initial objective called for particulate sampling of four to six engines each of smokeless and non-smokeless engines of the J52 and TF30 series to obtain a statistically reliable estimate of the particulate mass emissions from each gas turbine engine model. The overhaul schedule for these engines at NARF Alameda was such that the initial objective could be achieved only for the J52-P-8B (smokeless) engines.

CONCLUSIONS.

3. The J52-P-8B with smokeless combustors emitted less total particulates at idle and normal rated than did the J52-P-6B without smokeless combustors.
4. The TF30-P-408 with smokeless combustors emitted more total particulates at idle and maximum continuous power than did the TF30-P-6C without smokeless combustors.
5. The smokeless combustors in the J52 and TF30 engines will not have a significant effect on compliance with present particulate emissions standards at NARF Alameda and NARF San Diego (assuming that the standards apply to Navy activities) for the following reasons:

a. All the engines tested (smokeless and non-smokeless type) would comply with the Bay Area Air Pollution Control District (BAAPCD) limit for particulate loading (0.15 grains/SCF).

b. None of the engines tested (smokeless and non-smokeless type) would comply with the San Diego Air Pollution Control District (SDAPCD) limit for particulate loading (0.10 grains/SCF corrected to 12 percent carbon dioxide (CO₂)).

RECOMMENDATION.

6. There does not appear to be a need to install anti-pollution devices for particulates on the J52 and TF30 engine test cells at NARF Alameda. Particulate emissions from these engines meet the BAAPCD limit for particulate loading. However, consideration should be given to the installation of anti-pollution devices for particulates on test cells at NARF North Island (NORIS) and other NARF's that have equally stringent requirements if compliance to regulations is desired.

DESCRIPTION OF TEST EQUIPMENT

7. Particulate material emitted from test cell stacks is probably the most difficult pollutant to assess. One reason for this is that there is no agreement as to what particulate material is and how it should be measured. The definitions of particulate material vary and the amount collected depends on the method used. For example, Figure 1 shows the schematics of three different test methods used for sampling particulates.

8. Figure 1.a. is the Environmental Protection Agency (EPA) sampling train identified as Method 5 in the Federal Register (reference c). This method collects material at 250°F in the cyclone and the filter and defines this total as particulate material.

9. Figure 1.b. shows the BAAPCD particulate sampling train. This method defines particulates as material collected on an alundum or glass fiber filter at the stack temperature.

10. Figure 1.c. shows the Los Angeles Air Pollution Control District (LAAPCD) sampling train. In this method any materials condensed or caught in the impingers (which are at 70°F) and filter thimble downstream of the impingers are considered particulates. This method is the most severe method of measurement in that it collects all solids and condensible material at 70°F.

11. The situation as it exists presents a problem to the Navy since it has test cells scattered all over the United States, and different definitions of particulate emissions apply to these test cells. For the purpose of this report, particulate emissions include all particulate material plus condensible material. The particulate sampling equipment used for

the particulate measurement program at NARF Alameda was a modified LAAPCD sampling train. The modification consisted of the following:

- a. The filter was placed before the water filled impingers.
- b. The filter was heated to 200°F.
- c. The water filled impingers were placed in an ice water bath.

12. The J52 engine is described in reference d as an axial flow compressor engine with a multi-stage reaction turbine and nine through-flow combustion chambers, arranged in an annular space. The multi-stage axial compressor consists of a five-stage low pressure unit and a seven-stage high pressure unit. The low pressure compressor unit is connected by a through shaft to a single-stage low pressure turbine and the high pressure compressor unit is connected independently by a hollow shaft to a single-stage high pressure turbine. Individual differences in the models tested are as follows:

- a. J52-P-6B Turbojet Engine - this is the basic J52 engine containing no smoke reduction hardware. There is one fuel nozzle in each combustion chamber.
- b. J52-P-8B Turbojet Engine - this model incorporates smoke reduction combustion chambers.
- c. J52-P-408 Turbojet Engine - the J52-P-408 incorporates two position inlet guide vanes and smoke reduction combustion chambers with four fuel nozzles for each combustion chamber.

13. The TF30 turbofan engine is described in reference d as an axial-flow gas turbine engine with a can-annular burner having eight through-flow combustors, a nine stage low pressure compressor driven by a three-stage low pressure turbine, and a seven-stage high pressure compressor driven independently with a hollow shaft by a single stage high pressure turbine. The fan and compressor inlets are common and core and fan airflows are combined for discharge through a convergent jet nozzle. Characteristics of the engines tested are:

- a. TF30-P-6C Turbofan Engine - this model TF30 incorporates a three-stage fan and contains no smoke reduction hardware.
- b. TF30-P-408 Turbofan Engine - this model TF30 incorporates a two-stage fan, improved sea level performance and smoke reduction capability through an increased turbine inlet temperature and numerous part changes in the combustor (e.g. four nozzles per can), high and low pressure turbine and exhaust sections.

METHOD OF TEST

14. The engines tested during the course of this program were run two hours in addition to the normal engine acceptance run performed on all engines.

after overhaul. This permitted particulate sampling for one hour at idle and one hour at normal rated (J52)/maximum continuous (TF30) power. After an engine run was conducted at one power setting, the sampling probe and sample line along with the sampling apparatus containing the filter and water filled impingers were removed from the test cell. A second clean probe, sample line and sampling apparatus containing a clean filter and fresh distilled impinger water were then installed. The engine was then run at the second power setting. Clean equipment was used for each test run. Two complete and independent sets of particulate sampling equipment were used to minimize downtime between engine runs.

15. The modified LA sampling train, mentioned in the previous section was used to take particulate samples from each of the engines tested. A sample of exhaust gas was drawn by means of a vacuum pump through a heated (200°F) sampling probe and sample line, through a heated (200°F) glass fiber filter and then through each of five impingers which were cooled in an ice bath. The first two impingers contained 250 milliliters (mls) each of distilled water, the third contained silica gel to absorb any residual moisture and the last two were empty. The sample then passed through a regulating needle valve into the vacuum pump, a flow meter, a gas meter, and finally to the atmosphere. At the end of each engine run, a solvent (chloroform) was used to thoroughly wash out any particulate material adhering to the inner walls of the sampling probe and sample line. Chloroform was used because it evaporates very quickly in air without leaving a residue. This minimized the downtime needed to dry out the probe and sample line, as well as the possibility of introducing an unrelated contaminant. This solvent/particulate material mixture was collected in a clean plastic bottle. Secondly, the filter was carefully removed from its holder and placed in a plastic petri dish. Finally, the contents of the two water filled impingers were poured into a second clean plastic bottle.

16. The probe and line washings, filters and impinger water were returned to the Naval Air Propulsion Test Center (NAPTC) for laboratory analysis. The analysis can be broken down as follows:

a. Probe and line washings - each sample of solvent/particulate material mixture was emptied into a separate tared glass beaker. The solvent was allowed to evaporate until only the particulate material remained. The weight of the particulate material was determined by the following formula:

$$W_p = W_{gb} - W_{tb}$$

where: W_p = particulate weight.
 W_{gb} = gross weight of beaker.
 W_{tb} = tare weight of beaker.

b. Filter - the clean filters were weighed at NAPTC before the start of this program. Therefore, the weight of particulate material

deposited on the filter was determined by subtracting the weight of the clean filter from the weight of the same filter containing the particulate material.

c. Impinger Water - the impinger water collected the condensible material present in the exhaust gas. The condensible material can be broken down into solvent soluble and water soluble material.

(1) Solvent Soluble Material - a chloroform extraction was performed on each sample of impinger water. The impinger water was poured into a separatory funnel to which was added approximately 50 ml of solvent. The mixture was shaken vigorously for several minutes and then allowed to sit until the solvent and water visibly separated. The chloroform fraction was then drained off into a tared glass beaker. The extraction process was repeated three times for each sample. The solvent was allowed to evaporate until only the solvent soluble material remained. The weight of this material was determined as described in paragraph 16.a.

(2) Water Soluble Material - after the solvent extraction was completed, the water that remained was poured into a tared glass beaker and placed on a hot plate (below boiling temperature) to aid evaporation. After the water completely evaporated, only the water soluble material remained. The weight of this material was also determined by the difference between gross and tare weights.

ANALYSIS OF RESULTS AND DISCUSSION.

17. J52 Turbojet Engine

a. Table I gives a summary of the particulate data for all the runs and typical engine performance data are given in Table II. Figure 2 shows the total particulate density for the standard and smokeless J52 engines. The levels shown are the averages for all the runs on each type engine. The one set of particulate data obtained on the J52-P-408 is presented separately. Although this engine has smokeless combustors, the other parts changes incorporated in this engine model (e.g. four fuel nozzles per combustion chamber and two-position inlet guide vanes) require that a separate analysis be performed on its particulate emissions data. There was approximately a 20 percent average reduction in total particulate emissions at idle and a 21 percent reduction at normal rated power for the J52-P-8B engine as a result of the smokeless combustors. The total particulate levels for the single J52-P-408 engine tested were lower than those of the non-smokeless J52 by 10 percent at idle and 24 percent at normal rated power. These results indicate that the reduction in smoke levels attributed to the modified engines was achieved by combustion of some of the particulate matter or more complete combustion of the fuel.

b. A further understanding of the causes for the differences in particulate levels is obtained when the total particulate emissions are broken down and observed at each stage of collection.

(1) Probe and sample line (first area of collection) - as shown in Figure 3, the particulates collected from the probe and line generally do not show as great a difference between the smokeless and standard configurations as was seen with total particulates. A most significant point is the value at normal rated for the J52-P-8B engine, which is identical to the particulate levels at normal rated power for the J52-P-6B. These results indicate that the low smoke modification has little effect on the larger particles that tend to "fall-out" in the probe and line. The actual material collected from a J52-P-6B and a J52-P-8B is shown in Figure 4.

(2) Filter (second area of collection) - it is at the filter that the most dramatic difference is apparent. Figure 5 shows that there is approximately seven times more particulate material deposited on the filter for the J52-P-6B than for the J52-P-8B at idle and five and one-half times more material at normal rated. At idle the J52-P-8B engine with smokeless combustors shows very little particulate accumulation on the filters (Figure 6). The results with the J52-P-408 are similar to those with the J52-P-8B but the difference from the non-smokeless engine is not quite so pronounced. Since the larger particles in the overall particulate emissions fall out in the probe and sample line, the material on the filter is composed of the small particles. The large decrease in this portion indicates that the small particles are consumed in the combustion process. Since a similar filter sample is used to correlate with smoke production, the significant decrease in deposition at this point is consistent with the known smoke reduction achieved with the modified engines.

(3) Water filled impingers (third area of collection) - Figure 7 shows that the quantity of solvent soluble material from the J52-P-6B and the J52-P-408 is approximately the same as that from the J52-P-8B at normal rated. Significantly more solvent soluble material is collected in the impingers with both types of smokeless combustors than with the standard combustor. The evaporated residues are shown in Figure 8. As shown in Figure 9, there was no consistent trend between combustor types with respect to the water soluble material. The evaporated residues are shown in Figure 10. The solvent soluble and water soluble materials consist primarily of unburned or highly oxidized hydrocarbons of low molecular weight which are in a vapor state prior to being absorbed or condensed in the impingers. They have very little impact on total particulate levels and do not contribute to smoke production. Variations between the combustors in emission of these materials, therefore, are not considered significant factors.

18. TF30 Turbofan Engine - the particulate measurement data obtained for the TF30 engine do not represent a statistically acceptable source of information since only one of each engine model was tested. The data, which are also shown in Table I, were obtained on one TF30-P-408 engine and one TF30-P-6C engine. The performance data for these engines are shown in Table III. Figure 11 shows a 52 percent increase in total particulate emissions for the TF30-P-408 (smokeless combustor) at maximum continuous power. However, visible smoke at this power setting has been almost completely eliminated. This increase in total particulate emissions can be better understood by breaking down total particulate emissions and evaluating them at each area of collection.

a. Probe and sample line - the amount of particulate material collected in the probe and sample line at idle for the TF30-P-408 is slightly more than that for the TF30-P-6C as shown in Figure 12. At maximum continuous power, approximately 2.4 times more particulate material was collected for the TF30-P-408 than for the TF30-P-6C. Additional particulate testing is necessary to establish if this increase is characteristic of all TF30-P-408 engines.

b. Filter - Figure 13 compares particulate concentration on the filter for the TF30-P-408 and TF30-P-6C. Five times more particulate material was deposited on the filter for the TF30-P-6C than for the TF30-P-408 at idle and six times more material was collected at maximum continuous power. This information exhibits a similar trend to that observed for the J52 engine and is a further indication of more complete burning of small particles in the combustion system of the smokeless engine. It is also consistent with lower smoke emissions for the smokeless engine.

c. Water-filled impingers - as shown in Figure 14 the TF30-P-408 emitted three times more solvent soluble material at idle than did the TF30-P-6C and four times more at maximum continuous power. Although the solvent soluble material in the impingers is not a significant portion of total particulates (less than 2.5 percent), this result indicates that the smokeless TF30-P-408 may emit a higher level of unburned hydrocarbons at both idle and maximum continuous power. This fact should be verified since it does contribute to an increase of an undesirable pollutant.

d. Neither the TF30-P-408 nor the TF30-P-6C emitted any measurable amount of water soluble material.

19. The BAAPCD has their own method for sampling particulates (Figure 1.b.), but they do recognize the validity of data gathered using other equivalent methods (reference e). Therefore, the particulate sampling data collected during the course of this program using the modified LAAPCD sampling train would be acceptable to the BAAPCD and could be applied to their limits.

The BAAPCD assumes that it has legal jurisdiction over NARF Alameda and that Federal facilities will be treated the same as private industry. Regulation 2 of the BAAPCD defines four types of combustion operation: incineration, salvage, heat transfer and general combustion operation. BAAPCD states that a jet engine in a test cell falls under general combustion operation. This decision is significant since under a general combustion operation the particulate matter grain loading is exempted from a six percent oxygen correction which is applied to heat transfer, incineration and salvage operations. The normalization to six percent oxygen concentration in effect increases the particulate loading value measured at the stack exit. The limit for particulate grain loading at the stack exit is 0.15 grains per standard cubic foot (gr/SCF) of exhaust gas. The particulate grain loadings for the engines tested are presented in Figure 15, representing stack exit conditions. During an engine test augmentation air is aspirated into the stack and produces a dilution effect of approximately three to one. Figure 15 (with this dilution factor applied) shows that all the engines tested, with and without smokeless combustors, fall below the limit set by the BAAPCD.

20. Although this program was run at NARF Alameda which is under the jurisdiction of the BAAPCD, the SDAPCD deserves attention because San Diego does not breakdown the combustion process into various classes as does the BAAPCD. The limits apply across the board to all sources. This is a prime example of how pollution control legislation differs from area to area. Particulate matter concentration is required to be corrected to 12 percent CO₂ at the exhaust stack. This results in a significantly higher grain loading than the engine produces. The 12 percent CO₂ correction is used to prevent attempts to seek compliance by dilution of the pollutant with excess air. The correction is applied as follows:

$$\text{Particulates (corrected)} = \frac{12\% \text{ CO}_2}{\text{Stack CO}_2} \times \text{Particulates (measured)}$$

The SDAPCD uses an EPA sampling train (Figure 1.a.) for sampling particulates. They will however, accept data collected using other procedures after they evaluate the procedure and are convinced the data obtained are representative of the actual particulate loading (reference f). Figure 16 shows the corrected data, along with the SDAPCD limit for particulate loading. It is obvious from the graph that none of the engines tested with or without smokeless combustors would be acceptable. For this reason further investigation needs to be carried out to select an acceptable anti-pollution device if the SDAPCD limit were applied to test cells.

SUMMARY OF PARTICULATE DATA

Run No.	Engine/Serial No.	Power Setting	Probe and Line Material gms/m ³	Filter Material gms/m ³	Solvent Soluble Material gms/m ³	Water Soluble Material gms/m ³
1	J52-P-6B/650475	Idle	0.2875	0.0260	0.0041	0.0069
2	J52-P-6B/650475	NR	0.3548	0.1705	0.0026	0.0299
3*	J52-P-8B/650592	Idle	0.1674	0.0026	0.0077	0.0093
5	J52-P-8B/650592	Idle	0.1891	0.0028	0.0066	0.0125
3/5						
Average	J52-P-8B/650592	Idle	0.1782	0.0027	0.0071	0.0109
4	J52-P-8B/650592	NR	0.2994	0.0284	0.0010	0.0114
6	J52-P-408/678267	Idle	0.2606	0.0029	0.0120	0.0114
7	J52-P-408/678267	NR	0.2707	0.0610	0.0036	0.0125
8**	J52-P-8B/661381	Idle	-	-	-	-
9	J52-P-8B/661381	Idle	0.2523	0.0034	0.0081	0.0118
10	J52-P-8B/661381	NR	0.3870	0.0247	0.0058	0.0151
11	J52-P-6B/650152	Idle	0.3482	0.0094	0.0046	0.0097
12	J52-P-6B/650152	NR	0.3320	0.0899	0.0058	0.0022
13	TF30-P-408/664193	Idle	0.3753	0.0007	0.0095	0.0000
14**	TF30-P-408/664193	NC	-	-	-	-
15	TF30-P-408/664193	NC	0.8426	0.0406	0.0182	0.0000
16	TF30-P-6C/658306	Idle	0.3126	0.0037	0.0034	0.0000
17	TF30-P-6C/658306	NC	0.3547	0.2344	0.0047	0.0000
18	J52-P-8B/661184	Idle	0.2636	0.0017	0.0114	0.0000
19	J52-P-8B/661184	NR	0.3396	0.0056	0.0035	0.0000
20	J52-P-6B/636500	Idle	0.2408	0.0081	0.0106	0.0000
21	J52-P-6B/636500	NR	0.2899	0.0920	0.0027	0.0000
22	J52-P-8B/661623	Idle	0.2572	0.0009	0.0105	0.0009
23	J52-P-8B/661623	NR	0.2983	0.0266	0.0049	0.0000

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* Run number 5 was a rerun of run number 3. This was the first J52-P-8B engine tested and the exceptionally clean appearance of the filter after the run made the data suspect. However, the rerun (run number 5) produced similar results. Therefore, runs 3 and 5 were averaged together and used as one run for the purpose of data analysis.

** These runs were not completed due to engine problems arising during the test.

TABLE II
TYPICAL J52 ENGINE DATA

J52-P-6B:

Power Setting	Corrected Total Thrust, FN (lbs)	Corrected Compressor Speed, N ₂ (RPN)	Corrected Fuel Flow, W _f (PPH)	Inlet/ Temperature, T _{T2} (°F)	Air Flow, W _a (lb/sec)	Ambient Pressure PAMB (in./hg)
Idle	496	6,537	780	53	30*	30.16
Normal Rated	7,798	11,216	6,011	53	127**	30.17

* PWA Specification No. N-1731

** Reference d

J52-P-8B:

Idle	504	6,738	738	56	38*	20.08
Normal Rated	8,291	11,460	6,282	56	130**	30.07

* PWA Specification No. N-1844

** Reference d

J52-P-408:

Idle	525	6,689	769	58	40*	30.02
Normal Rated	10,105	11,600	8,142	55	137**	30.01

* PWA Specification No. N-6128

** Reference d

NAPTC-PE-48

TABLE III
TYPICAL TF30 ENGINE DATA

TF30-P-6C:

Power Setting	Corrected Total Thrust, FN (lbs)	Corrected Compressor Speed, N ₂ (RPM)	Corrected Fuel Flow, W _f (PPH)	Inlet/ Temperature, T _{T2} (°F)	Air Flow, W _a (lb/sec)	Ambient Pressure PAMB (in./Hg)
Idle	875	8,887	820	69	55*	29.87
Maximum Continuous	9,844	13,748	5,920	70	225*	29.87

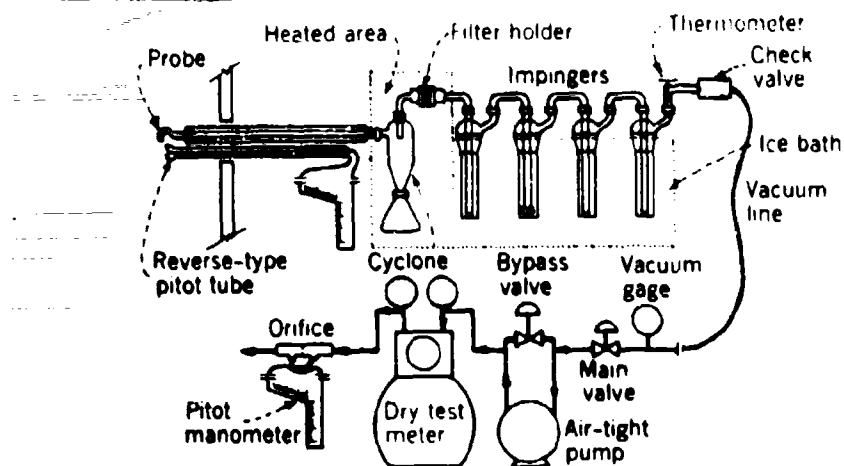
* PWA Specification No. N-1832

TF30-P-408:

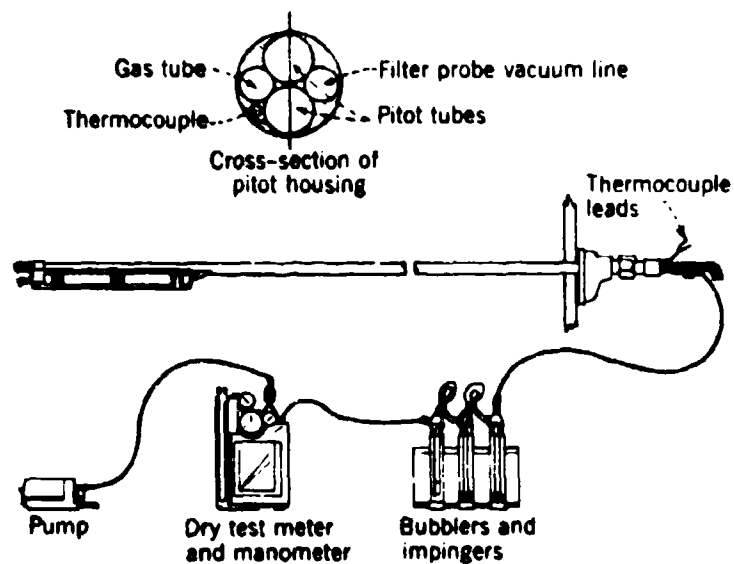
Idle	973	9,039	894	64	72*	30.02
Maximum Continuous	11,282	13,928	6,566	72	232*	29.99

* PWA Specification No. N-6134

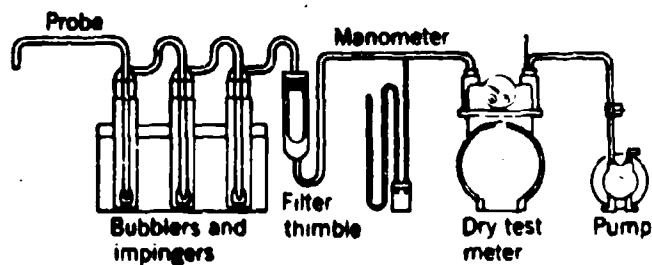
SCHEMATICS OF PARTICULATE MEASUREMENT SYSTEMS



a). **EPA** particulate-sampling train

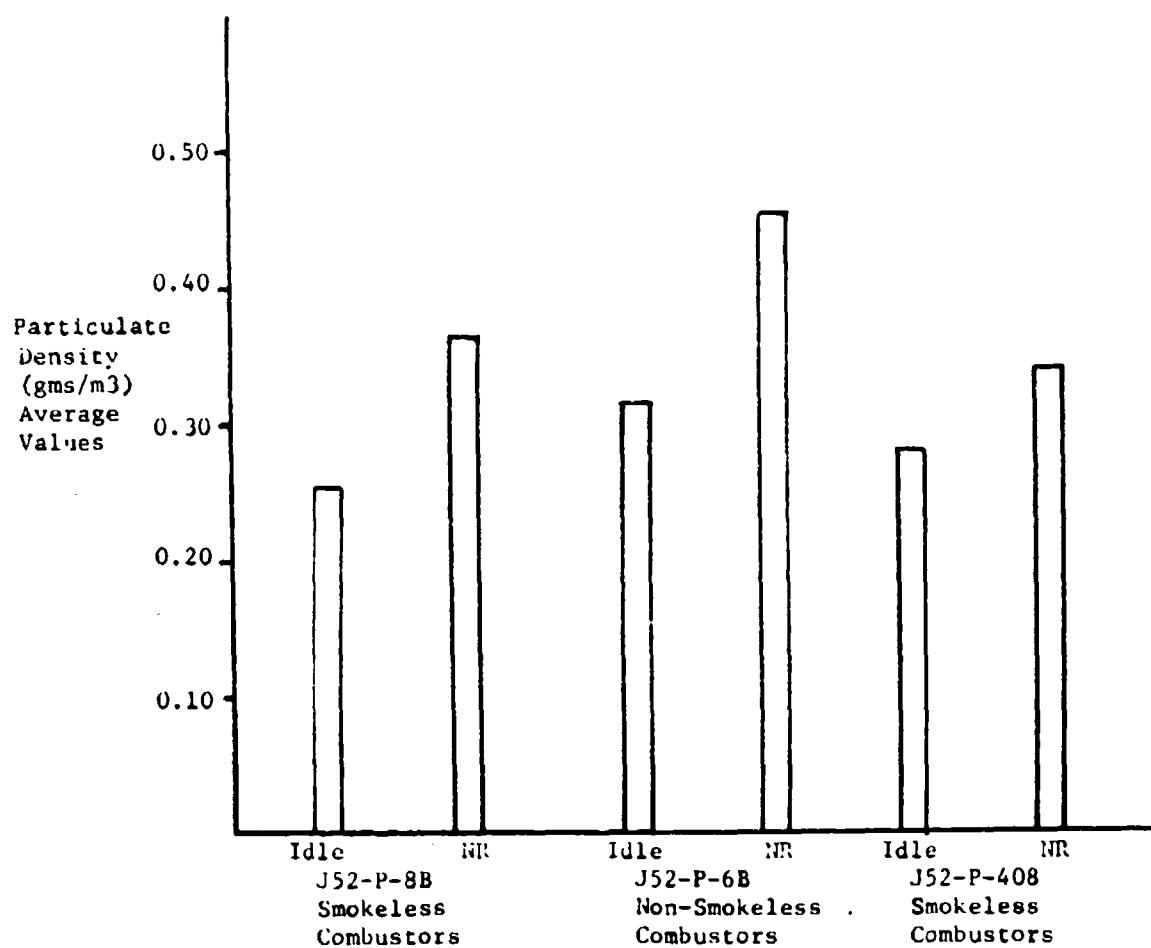


b). **BAAPCD** particulate-sampling train

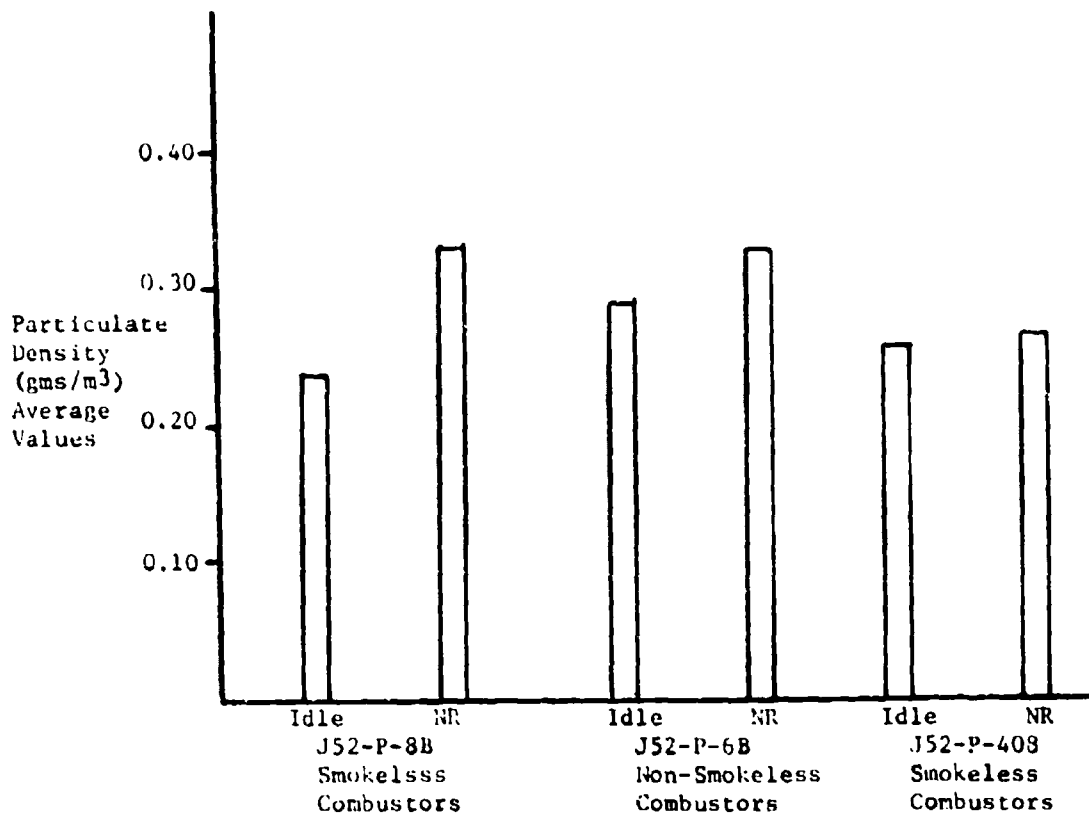


c). **LAAPCD** particulate-sampling train

PARTICULATE DENSITY (TOTAL PARTICULATES) FOR
J52-P-8B, J52-P-6B AND J52-P-408 ENGINES



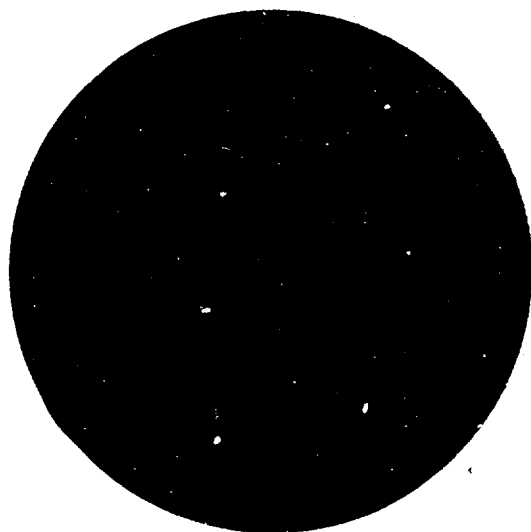
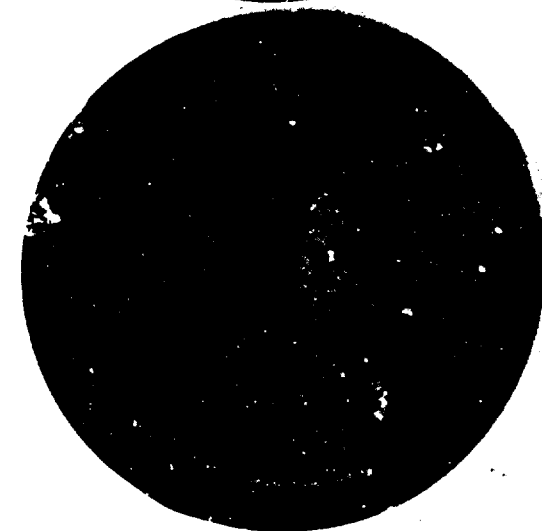
PARTICULATE DENSITY (PROBE AND LINE WASHINGS)
FOR J52-P-8B, J52-P-6B AND J52-P-408 ENGINES



PHOTOGRAPHIC COMPARISON OF PROBE AND LINE WASHINGS
FOR J52-P-8B AND J52-P-6B ENGINES

IDLE

NORMAL RATED

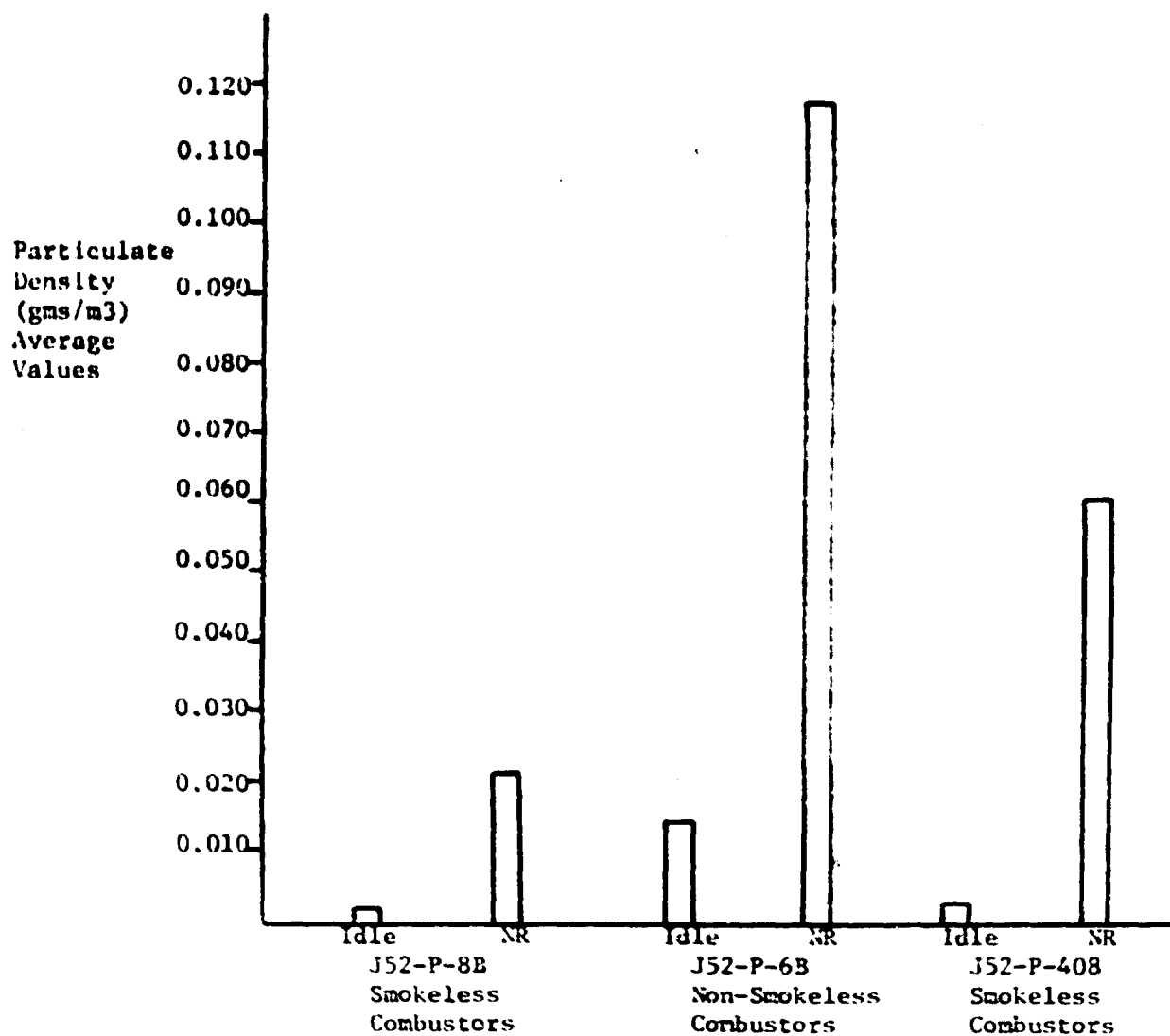


J52-P6B NON-SMOKELESS
COMBUSTORS



J52-P8B SMOKELESS
COMBUSTORS

PARTICULATE DENSITY (FILTER ONLY) OF
J52-P-8B, J52-P-6B AND J52-P-408 ENGINES



PHOTOGRAPHIC COMPARISON OF FILTERS
FOR J52-P-8B AND J52-P-6B ENGINES

IDLE

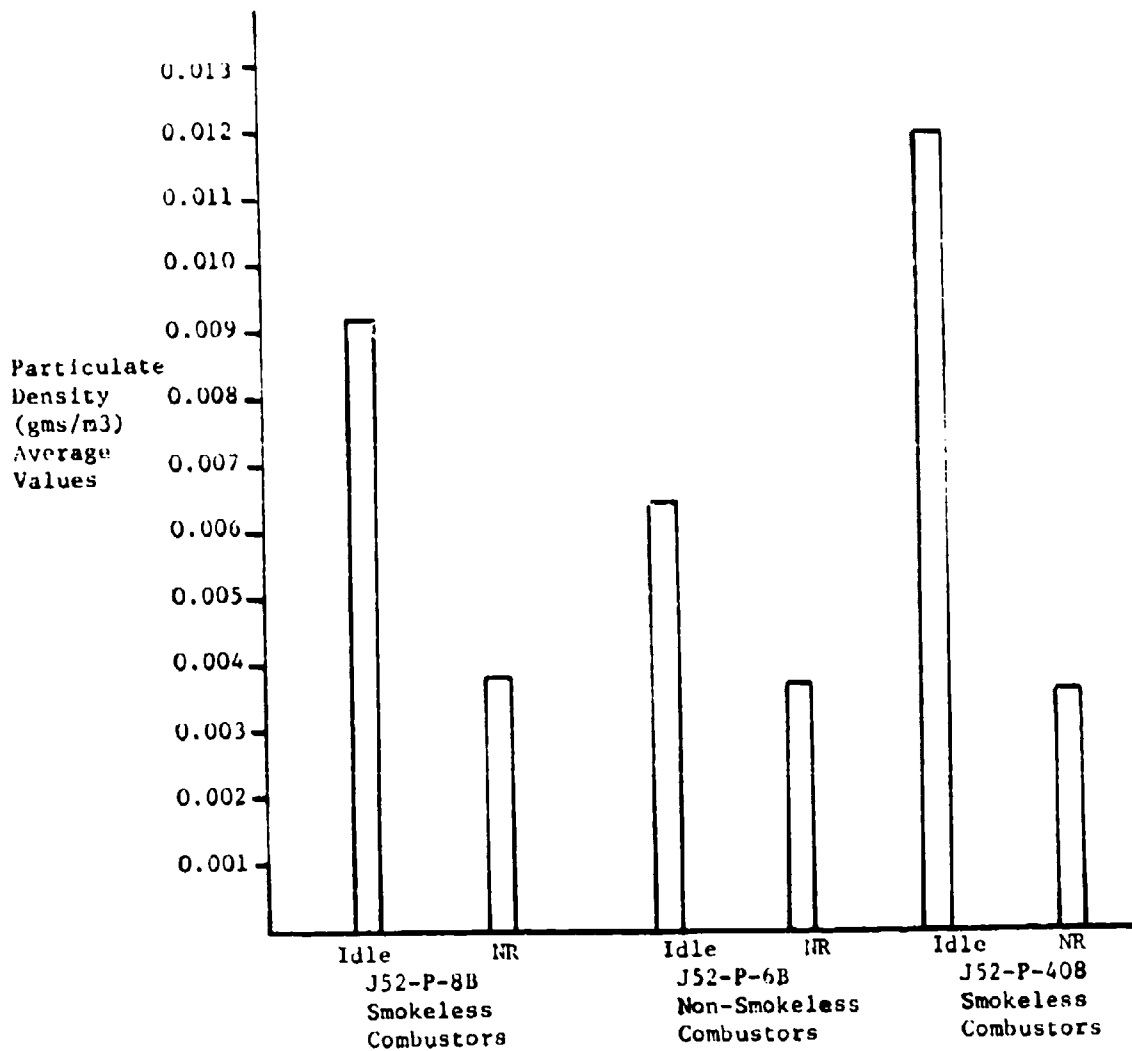
NORMAL RATED



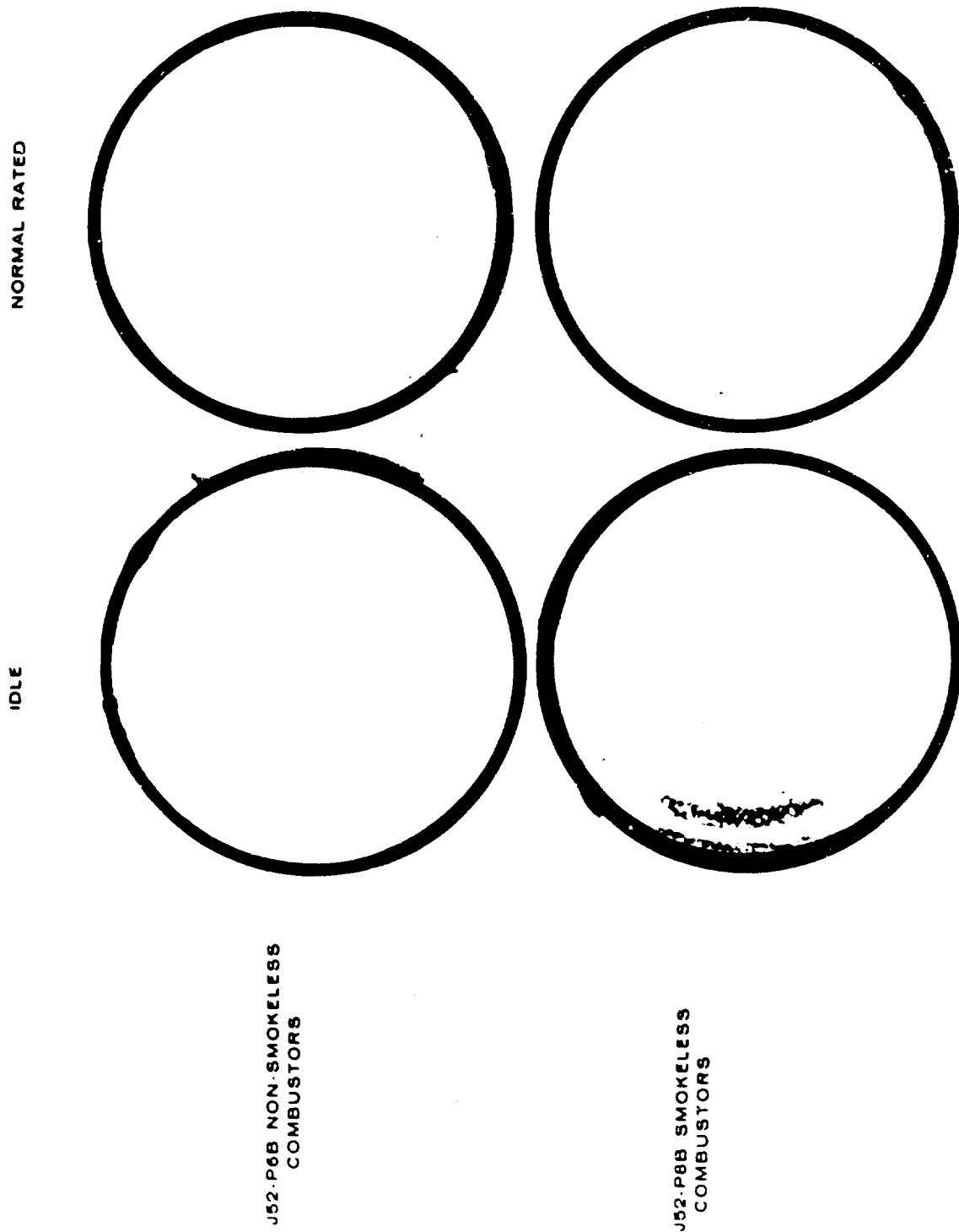
J52-P-6B NON-SMOKELESS
COMBUSTORS

J52-P-8B SMOKELESS
COMBUSTORS

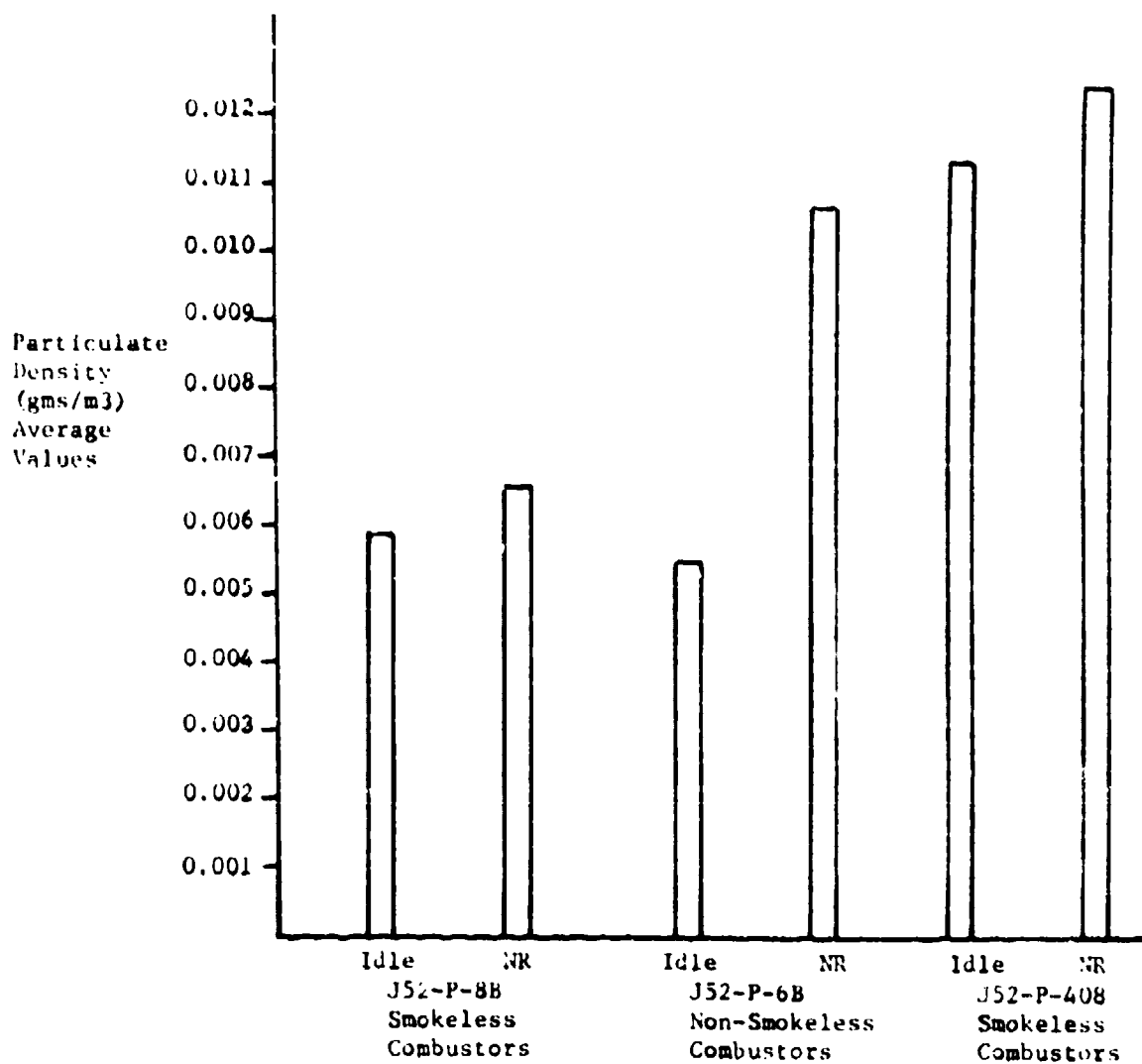
PARTICULATE DENSITY (SOLVENT SOLUBLE MATERIAL)
FOR J52-P-8B, J52-P-6B AND J52-P-408 ENGINES



PHOTOGRAPHIC COMPARISON OF SOLVENT SOLUBLE MATERIAL
FOR J52-P-88 AND J52-P-68 ENGINES



PARTICULATE DENSITY (WATER SOLUBLE MATERIAL)
FOR J52-P-3B, J52-P-6B AND J52-P-408 ENGINES



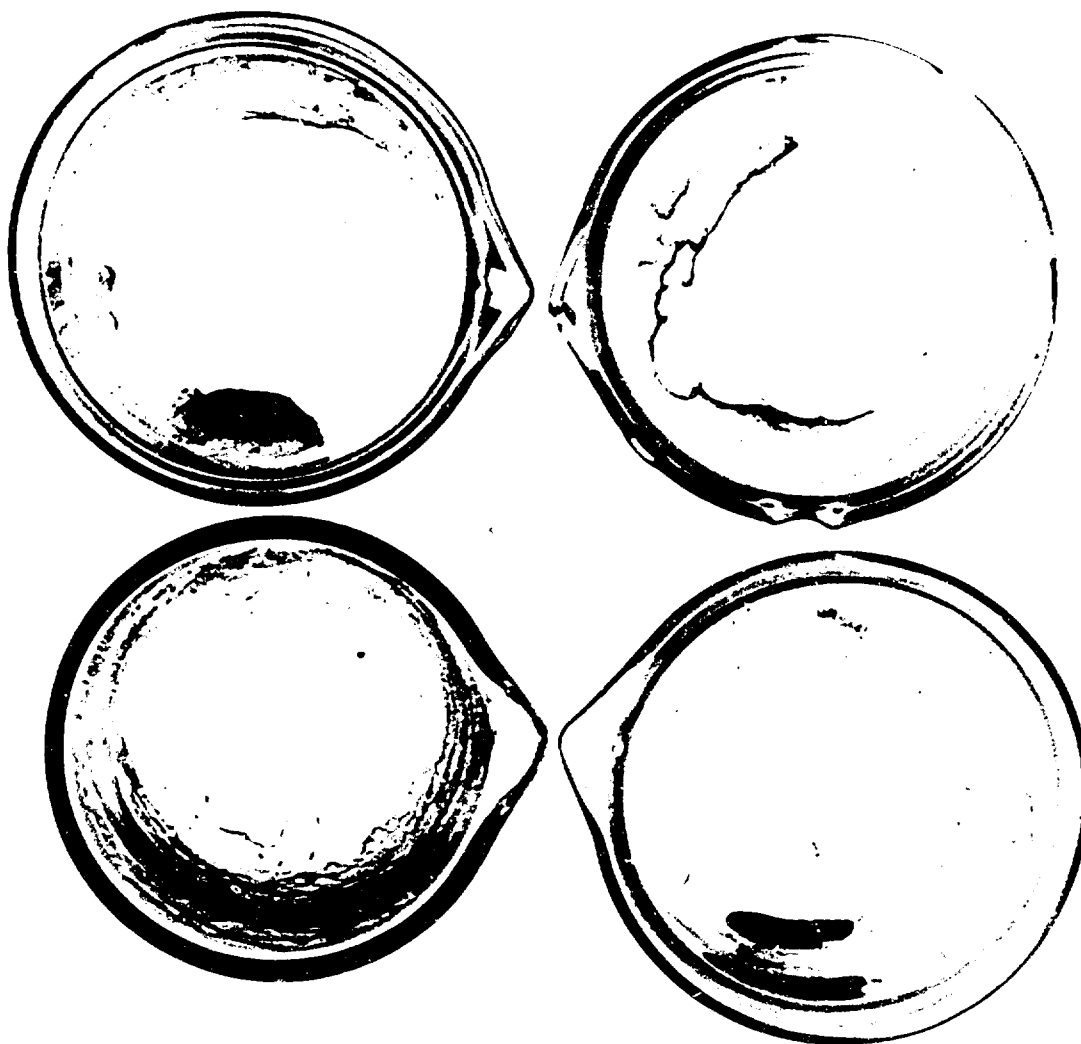
PHOTOGRAPHIC COMPARISON OF WATER SOLUBLE MATERIAL
FOR J52-P.88 AND J52-P.68 ENGINES

IDLE

NORMAL RATED

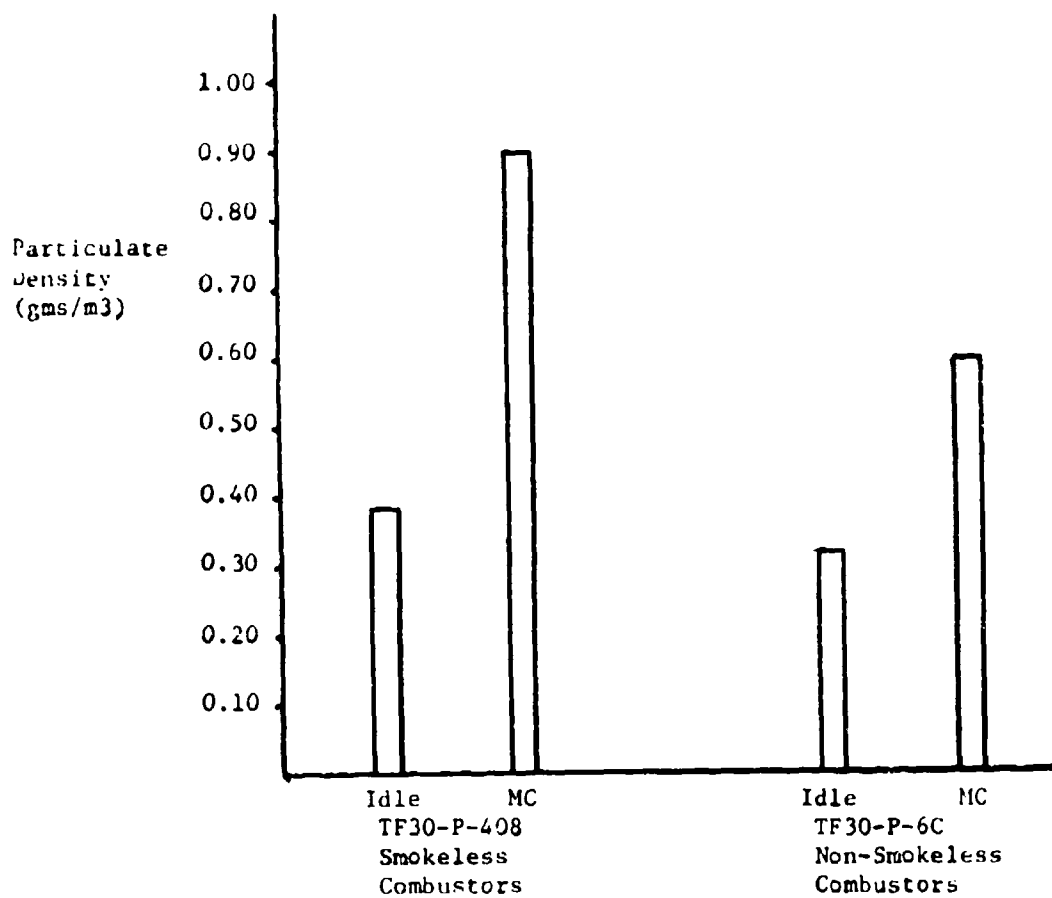
J52-P68 NON-SMOKELESS
COMBUSTORS

J52-P88 SMOKELESS
COMBUSTORS



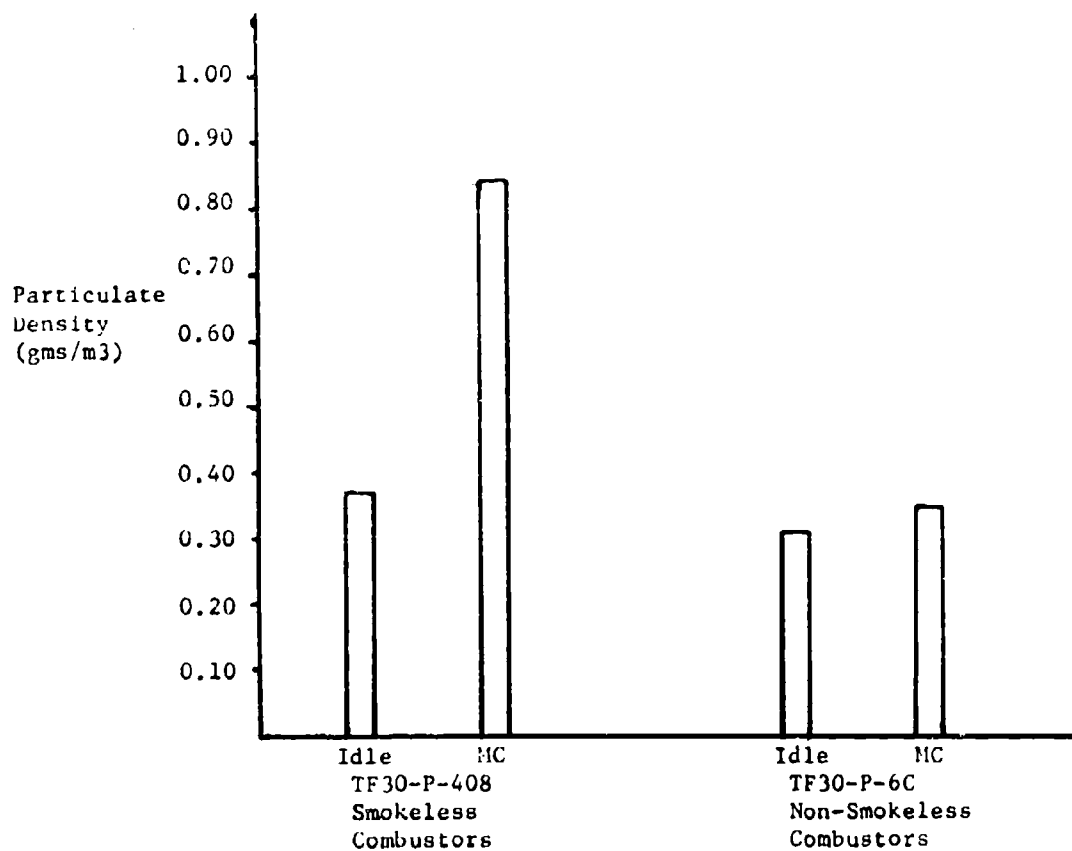
PARTICULATE DENSITY (TOTAL PARTICULATES) FOR
TF30-P-408 AND TF30-P-6C ENGINES

NOTE: ONLY ONE ENGINE OF EACH TYPE WAS TESTED



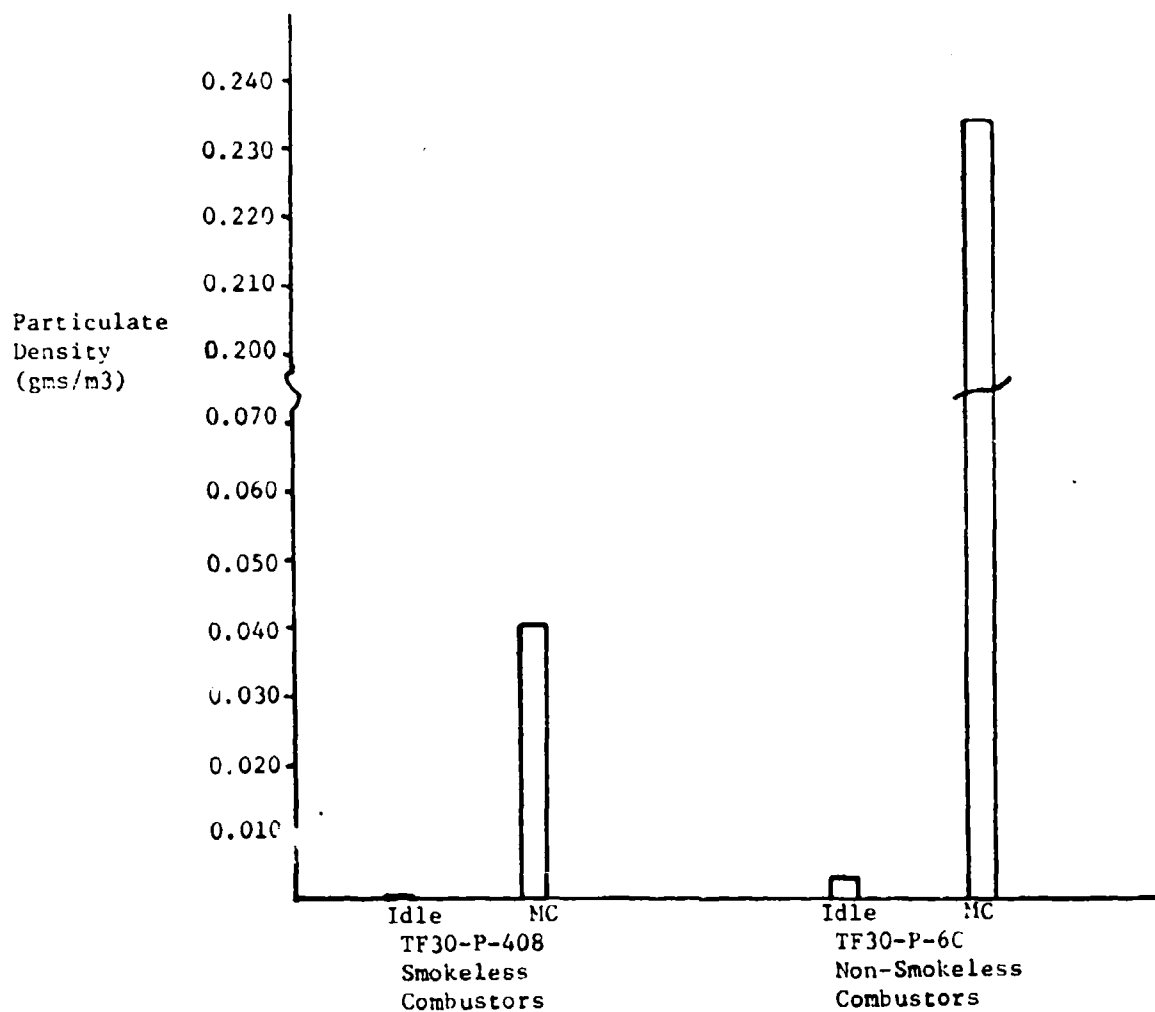
PARTICULATE DENSITY (PROBE AND LINE WASHINGS) FOR
TF30-P-408 AND TF30-P-6C ENGINES

NOTE: ONLY ONE ENGINE OF EACH TYPE WAS TESTED



PARTICULATE DENSITY (FILTER ONLY) FOR
TF30-P-408 AND TF30-P-6C ENGINES

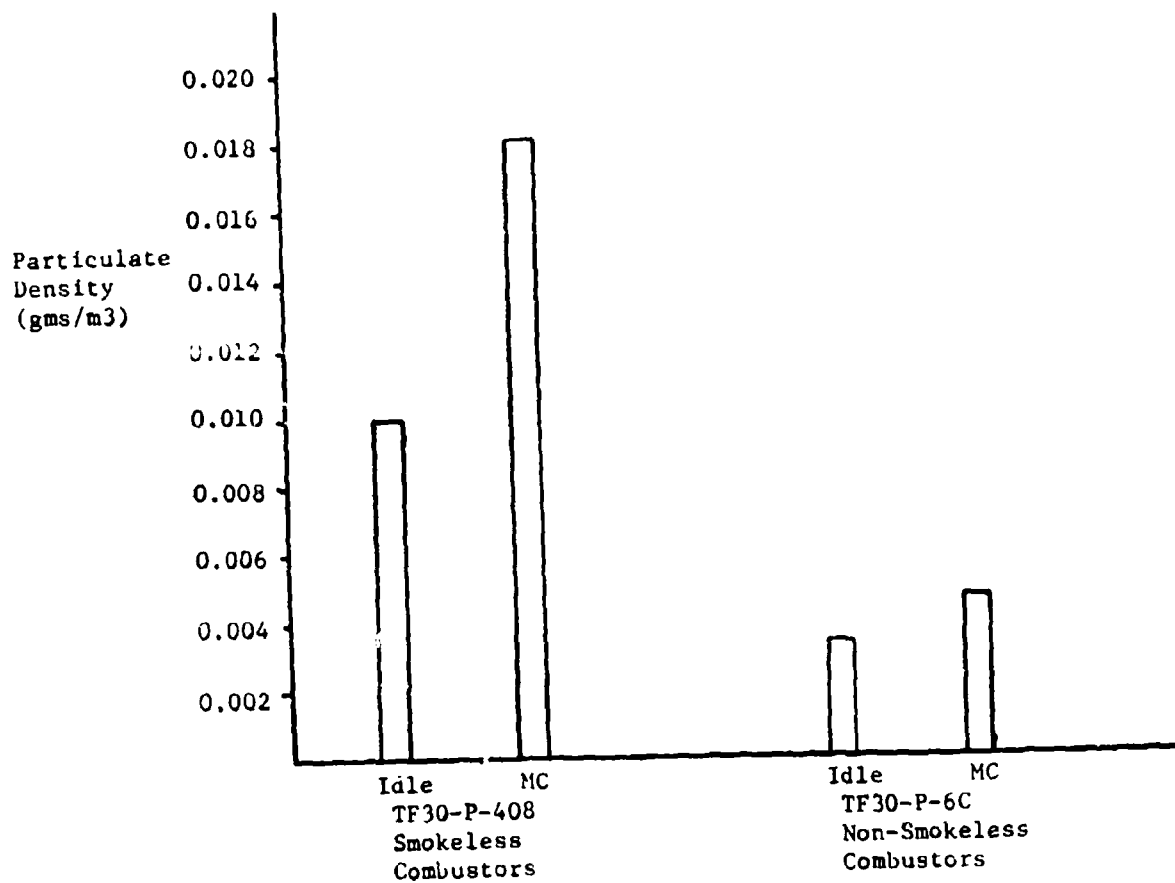
NOTE: ONLY ONE ENGINE OF EACH TYPE WAS TESTED



PARTICULATE DENSITY (SOLVENT SOLUBLE MATERIAL)

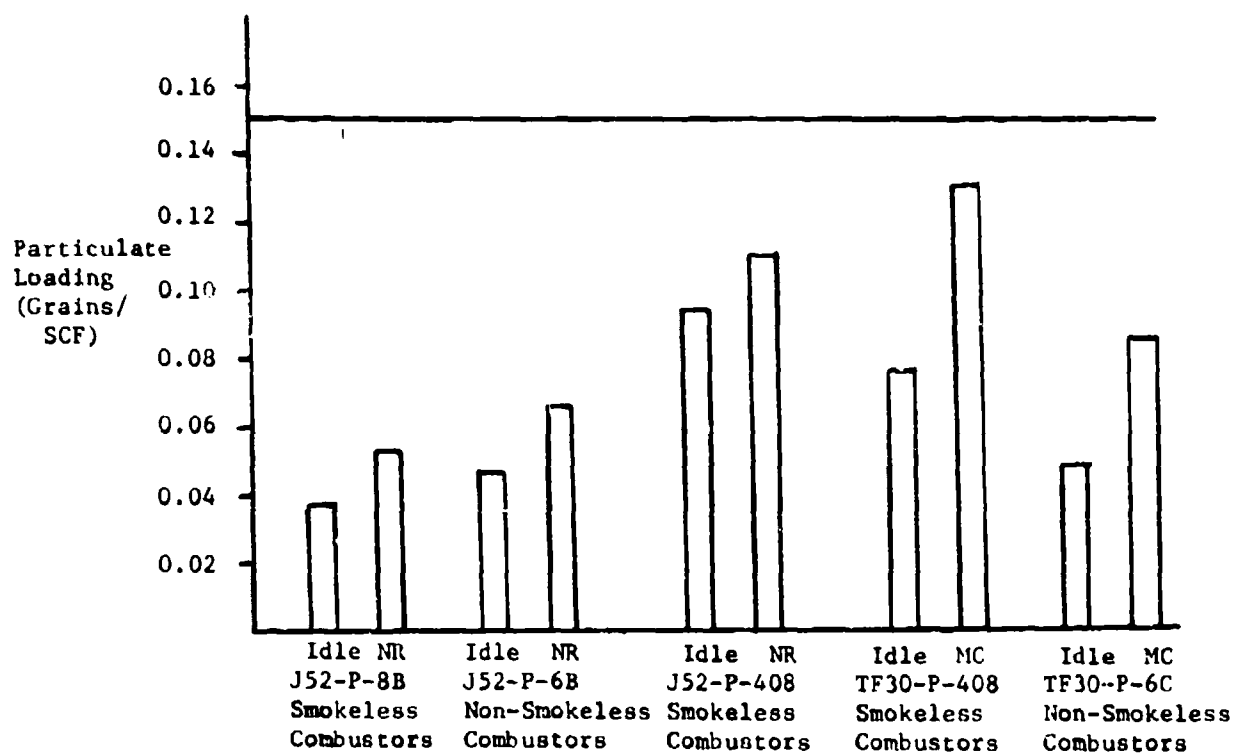
FOR TF30-P-408 AND TF30-P-6C ENGINES

NOTE: ONLY ONE ENGINE OF EACH TYPE WAS TESTED

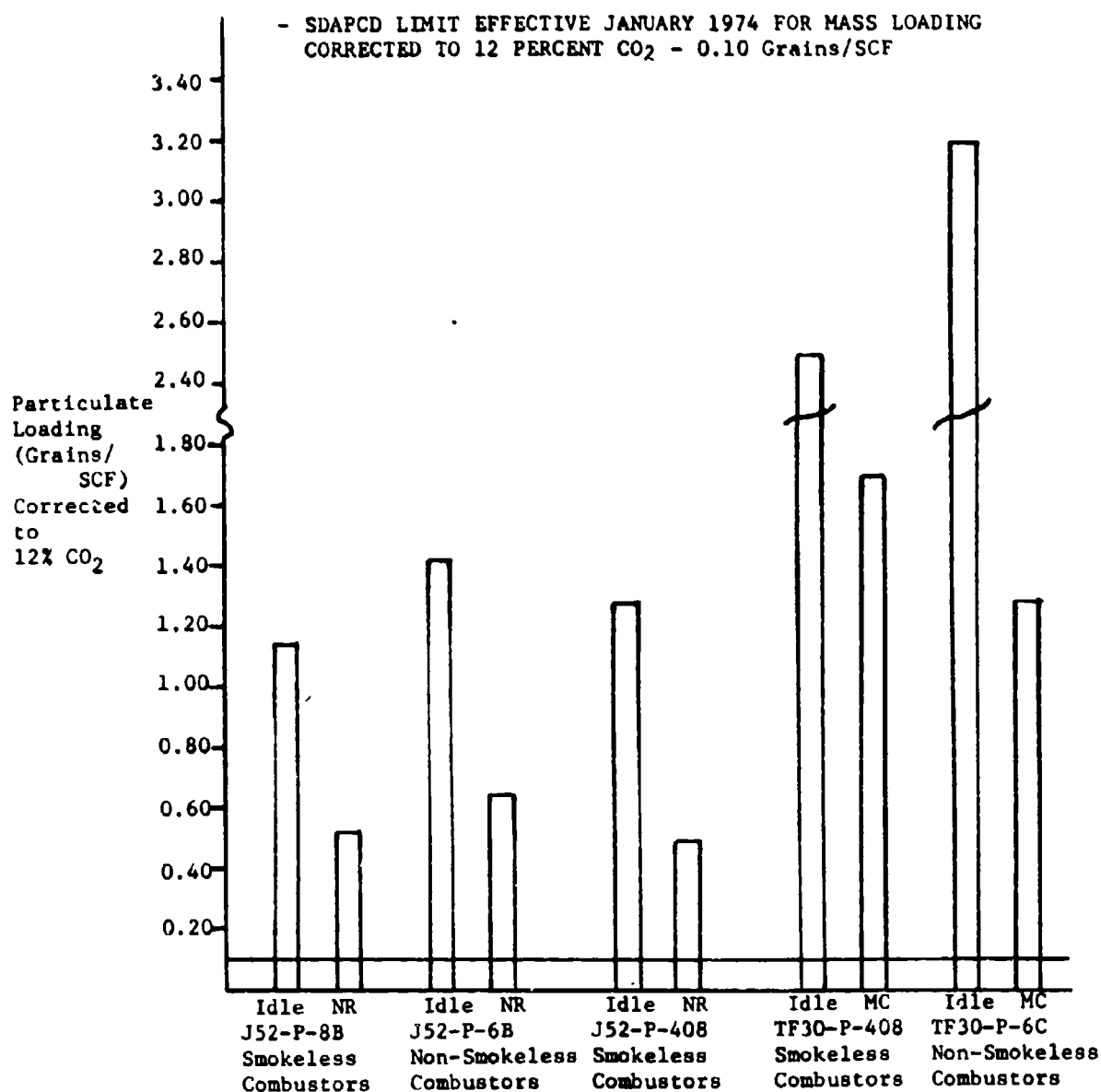


BAAPCD LIMIT FOR STACKS COMPARED TO
J52 AND TF30 EXHAUST STACK PARTICULATE LOADING

- BAAPCD LIMIT - 0.15 Grains/SCF



SDAPCD LIMIT FOR STACKS COMPARED TO J52
AND TF30 EXHAUST STACK PARTICULATE LOADING



REFERENCES:

Reference material noted in this report is as follows:

- a. NAPTC-PE-3 Final Report on Work Unit Assignment No. NAEC (GSED P.O. 2-8034), October 1972, A Survey of The Air Pollution Potential of Jet Engine Test Facilities, H. E. Lindenhofen, Project Engineer.
- b. NAPTC Ltr PE71:AFK:er 10340 Ser F1072 dated 10 December 1973, Request to Conduct Particulate Test Program on Engines at the Naval Air Rework Facility Alameda.
- c. Federal Register, Vol 38, No. 136, Part II, Tuesday, July 17, 1973, Environmental Protection Agency, Control of Air Pollution from Aircraft and Aircraft Engines, Emission Standards and Test Procedures for Aircraft.
- d. NAVAIR 00-110A-3 U.S. Navy Propulsion Characteristics Summary, August 1973.
- e. Private Communication, D. Karels, Chief of Source Test, Bay Area Air Pollution Control District, December 1974.
- f. Private Communication, M. Foley, Air Pollution Chemist, San Diego Air Pollution Control District, December 1974.